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A Programmer/Analyst's Guide to the Multisatellite Fourier Analysis System

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Code 664

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I. INTRODUCTION

This paper is largely a collection of excerpts from, MFAP, "The Multisatellite Fourier Analysis Program", Jenny S. Jacques, October 1980. It is slightly more compact in areas not necessary to adding a new satellite, and expands on other slightly neglected areas such as coordinate systems. This paper, used with the MFAP paper should supply all the needed instructions to add a new data source or satellite to the system.

II. BACKGROUND

A. General:

Some spacecraft experiments collect data as they spin on an axis. One spin cycle circumscribes a circle, which may be divided into any number of sectors. This data is referred to as "sectored data" or "sectored rates", each sector representing a flux of desired energy wavelength in the direction in which the detector is pointing (See Figure 1). The Multisatellite Fourier Analysis System uses this sectored data to perform a Fourier Analysis[1], calculating the first three harmonics. All satellites in this system must have exactly eight sectors.

The following outputs may be generated:

1. Fourier listing of flux, a "flow parameter", the anisotropics and angles, and the sectored counts. The listing may also included angle corrections to the sectors and magnetic field values.

2. Plots of flux vs. time.

[1]"Limitations of the COS Approximation as Applied to the Cosmic-Ray Anisotropy," Nuclear Instruments and Methods, #138 (1976) pages 191-199, R.D. Zwickl and W.R. Webber.

3. Multi-variable plots of anisotropy values and anistropy angles vs. time. The anisotropy values vs. time are plotted above the anisotropy angles vs. time.

4. Cam plots of the sectored counts, and, if desired, magnetic field cam histograms of the north-south and planar directions with an arrow on the rates cam plots indicating direction of field.

5. Output tape of the sector counts for use with other programs.

6. Output tape of the Fourier results for use with other programs.

All plots may be sent to either the SD4060 plotter or the Calcomp plotter.

B. Software Structure:

The Multi-satellite Fourier Analysis Program is a system of subroutines that may be divided into two sets: (See Figure 2)

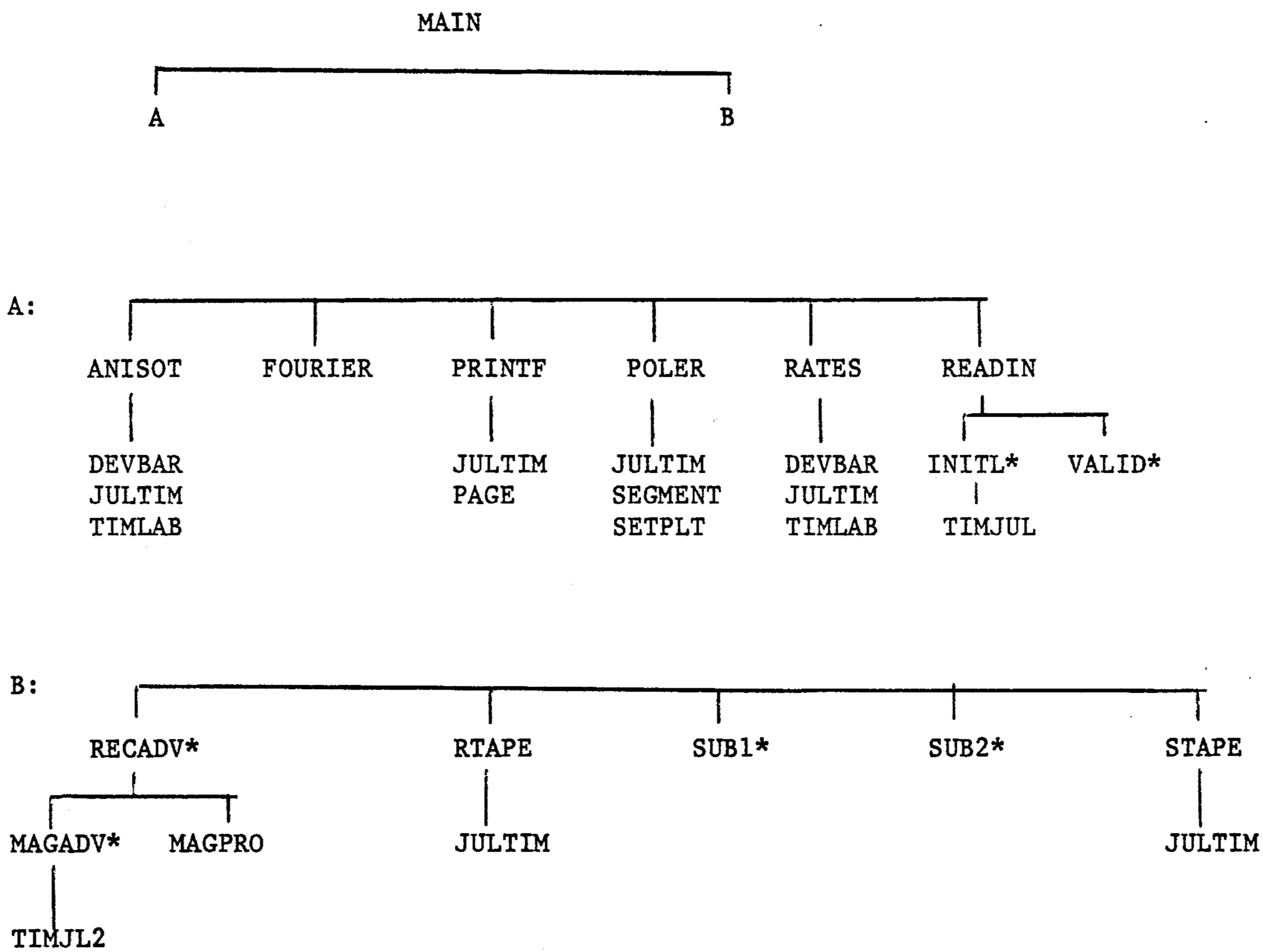
i) The satellite independent modules (SI)
ii) The satellite dependent modules (SD)

The system is organized such that any satellite data can link into the SI modules by supplying the correct SD modules. The system then outputs Fourier analyzed data in the form of listings and/or plots. This saves design, coding, and testing time for all analysis, listing, and plotting routines.

Another feature of flexibility in this program is the use of two subroutines, SUB1 and SUB2, which are called immediately prior to and after the Fourier analysis routine. This allows the data to be manipulated in any way the user desires before being output. The default routines simply return. To invoke changes in this way, a routine by the same name is created in load form and linked before the Fourier program modules. Thus, these routines are used in place of the dummy routines.

Block Diagram

* Note: All modules followed by an asterisk (*) are satellite-dependent (SD) codes



System Configuration

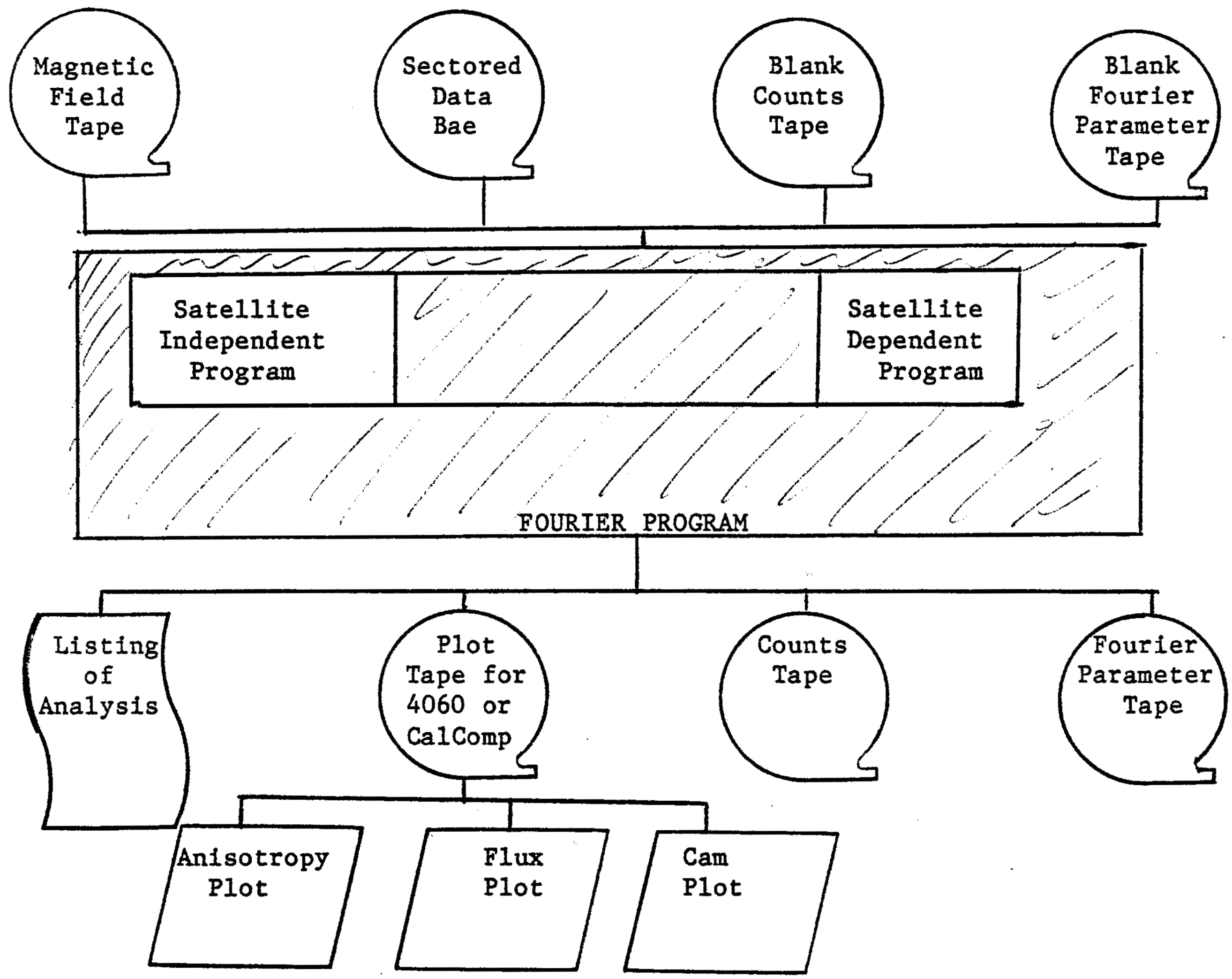


Figure 2

Modules Definitions

Subroutine	Function
ANISOT	Plots the anisotropies and the PHI angles
DATFIL	Fills the counts and accumulation time arrays for the rates
DEVBAR	Plots the error bars for anisotropy and rate plots
FOURIER	Performs Fourier analysis, returning results in common
INITL (SD)	Initializes the label, weight, phi0, geometric factor arrays
JULTIM	Converts Julian date into yr, mon, dy, hr, mn, sc
MAGADV (SD)	Advances the magnetic field tape, reads record
MAGPRO	Fills the magnetic field COMMON and writes to disk
PAGE	Called from PRINTF to write the page headers
POLER	Plots counts vs. sector on a polar plot, has magnetic field option
PRINTF	Prints the Fourier series coefficient results
RATES	Plots the rates vs. time
READIN	Reads the input namelist, performs data checks
RECADV (SD)	Reads in a new average from the sectored rates tape
RTAPE	Creates a tape containing the Fourier results
SEGMNT	Plots a line segment, arrow head, or whole arrow
SETPLT	Sets the scaling for polar plots
STAPE	Creates a sector counts tape
SUB1,SUB2	Dummy subroutines, substituted for by user JCL if desired
TIMJUL	Converts yr, mon, dy, hr, mn, sc to modified Julian time
TIMLAB	Labels the time axis for anisotropy and rates plots
VALID (SD)	Validates the user input data

C. User Input:

The user input to this system consists of stacked namelist sets. A namelist set consists of one or more namelists which define input and output options. There are at most five namelists for the SI code. The first one must always be INPUT. Depending on the options in INPUT, the other namelists are required, one for each output option chosen: (Refer to pages 2.B-1 to 4 of MFAP[2])

Input Member - .True.	Requires this Namelist
QPRINT	PRINTR
QPLOT	PLOTS
QTAPES	TAPES
QMAGNT	MAGNT

In addition, any SD namelists which the SD code requires can be listed at the end of each namelist set. The program processes each set in sequence until there are not more sets. If a tape was used in the previous set and is to be used in the current set it is left mounted, merely rewound to the beginning.

III. FORMULAE

The following formulae are used in the system.

A. Fourier Formulae:

The following expression for the rate is used:

$$C_i = A_o[1 + \sum_{n=1}^{3} \xi_n \cos n(\phi_i - \phi_n)]$$

where

$$A_o = \frac{1}{8G} \sum_{i=1}^{8} C_i,$$

C_i = sector rate

[2]"The Multisatellite Fourier Analysis System", Jenny S. Jacques, October 1980

$$\xi_n = A_n/A_o,$$

$$A_n = (a_n^2 + b_n^2)^{1/2},$$

$$a_n = \frac{W_n}{4} \sum_{i=1}^{8} C_i \cos(n\theta_i),$$

$$b_n = \frac{W_n}{8} \sum_{i=1}^{8} C_i \sin(n\theta_i),$$

θ_o = angle measured counter-clockwise from reference direction to the center of sector ϕ.

i = angle in direction of Sector i,

$$\theta_n = \frac{1}{n} \tan^{-1}(b_n/a_n) + \theta_o,$$

n = harmonic number

i = sector number,

W_n = given weight factor, predetermined, and

G = geometric factor of counter (cm^2ster).

For 8 sectors, θ_i is a mutliple of 45°, so the values for $\cos(n\theta_i)$ and $\sin(n\theta_i)$ may be predetermined, saving CPU time. The result is then rotated through the angle θ_o so that the final answer is with respect to the north reference direction (usually the sun).

The following formulae for standard deviation is used:

$$\sigma_{A_o} = (A_o/8G)^{1/2}$$

$$\sigma_{\zeta_n} = W_n([1 + D_n]/4A_o)^{1/2}$$

$$\sigma_{\phi_n} = W_n([1 - D_n]/4n^2\zeta_n^2A_o])^{1/2}$$

$$D_n = (W_n^2/8A_o^3{}_n^2)(\sum_{i=1}^{8} [(a_n^2 - b_n^2)\cos 2n\theta_i + 2a_nb_n \sin 2_n\theta_i]C_i)$$

$$flow = (a_1 + a_3*\cos(3*\theta_i - \theta_3))/(a_1 + a_2 \cos(2*\theta_1 - \theta_2))$$

B. Magnetic Field:

Phi: Longitude: lies in the ecliptic plane and the sectors progress counter-clockwise when viewed from above the plane (north). (24 sectors)

Theta: Latitude: perpendicular to the ecliptic plane, with sectors progressing from +90° to -90° in the clockwise direction, measuring distance from the plane. (12 sectors)

$+\hat{Z}$ = North
$+\hat{X}$ = From Sun to spacecraft
$+\hat{Y} = \hat{Z} \times \hat{X}$

ϕ = Phi = $\tan^{-1}(y/x)$

θ = Theta = $90-\cos^{-1}(Z)$ (latitude) (See Figure 3)

$$\Delta B = (\langle|B|^2\rangle - \langle|B|\rangle^2)^{1/2}$$

$$\Delta\phi,\Delta\theta = \left[\frac{\sum_{i=o}^{n} N_i\phi_i^2}{\sum_{i=o}^{n} N_i} - \left(\frac{\sum_{i=o}^{n} N_i\phi_i}{\sum_{i=o}^{n} N_i}\right)^2\right]^{1/2}$$

where n=23 for ϕ, 11 for θ

($\Delta\phi$ is calculated using the sector with the most counts as the center for the distribution.)

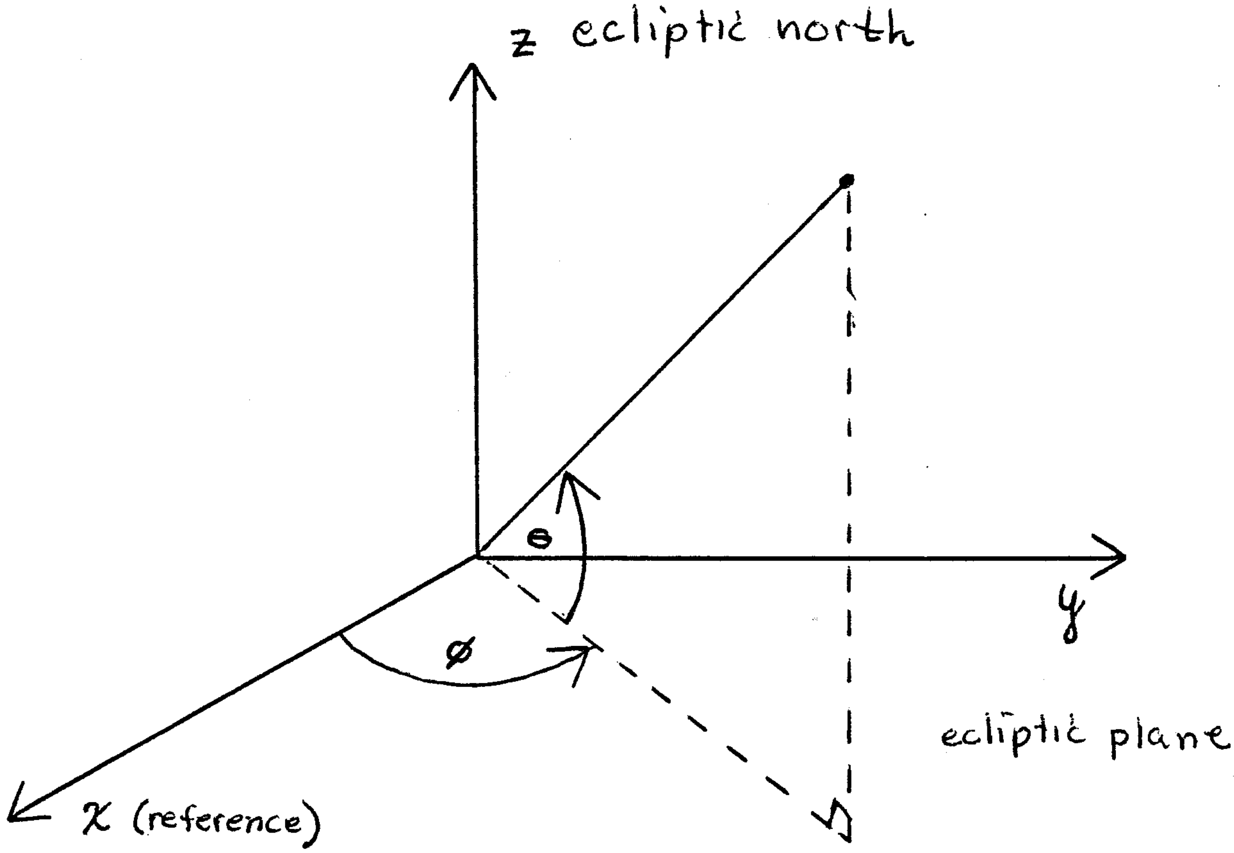


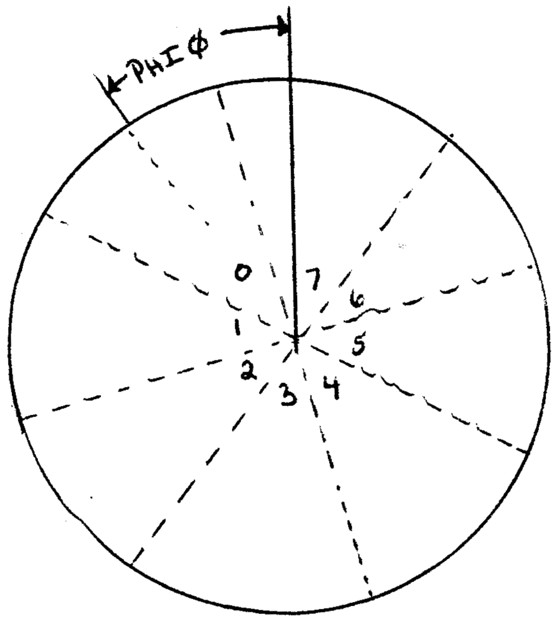
Figure 3

IV. COORDINATE SYSTEMS

A. Sectored Counts:

The coordinate system for the sectored counts is the plane of rotation of the satellite. The sectors are numbered counter-clockwise from 0 to 7, so each sector represents 45° of space.

The reference direction is the vertical:



If a spacecraft spins in the opposite direction, clockwise, the routine which reads the data must reverse the order of the sectors in the common RATDAT. Then all output and formulae will apply perfectly. The PHIO arrays which contain the angle from reference to the center for sector 0 measured counter-clockwise must be changed to measure the center of sector 7.

If a spacecraft has more than 8 sectors, they can be combined in some fashion in the READIN subroutine to simulate 8 sectors. For less than 8 sectors, they may be divided to simulate 8 sectors.

The COMMON block RATDAT expects the COUNTS(9,6) array to contain the counts in order of sector 0-7 in elements (1-8,N), for the N^{th} rate. The 9^{th} element is the sum of the 8 counts. The ACCUM array is the accumulation time for the counts in each rate N. For the rest of the RATDAT variables, see page 2.A-12 in MFAP.

B. Magnetic Field:

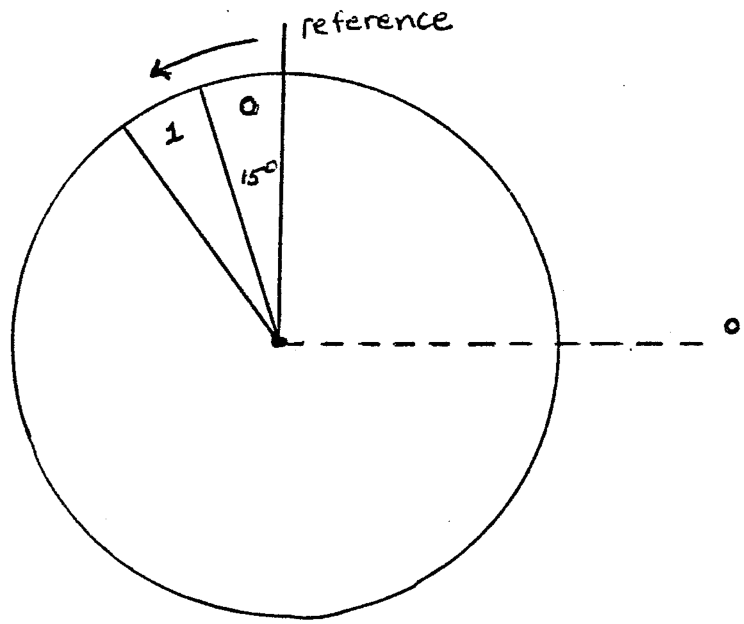
The magnetic field's coordinate system is described in Figure 3, Section II.B. The THETA as printed in all output is the latitude angle measured from the ecliptic plane. The PHI value is the angle measured counter-clockwise from the reference direction.

The COMMON block MAGFLD expects the PHI histogram QPSECT to consist of 24 sectors spanning 360°, with the sector 0 being the first sector counter-clockwise from reference. The THETA histogram QTSECT consists of 12 sectors spanning 180° with the first sector being measured clockwise from the north ecliptic pole. These are the true spherical coordinates. However, on output, a latitude is more meaningful then the angle measured from north, so the angle $90° \cos^{-1} Z$ is used. See Figure 4.

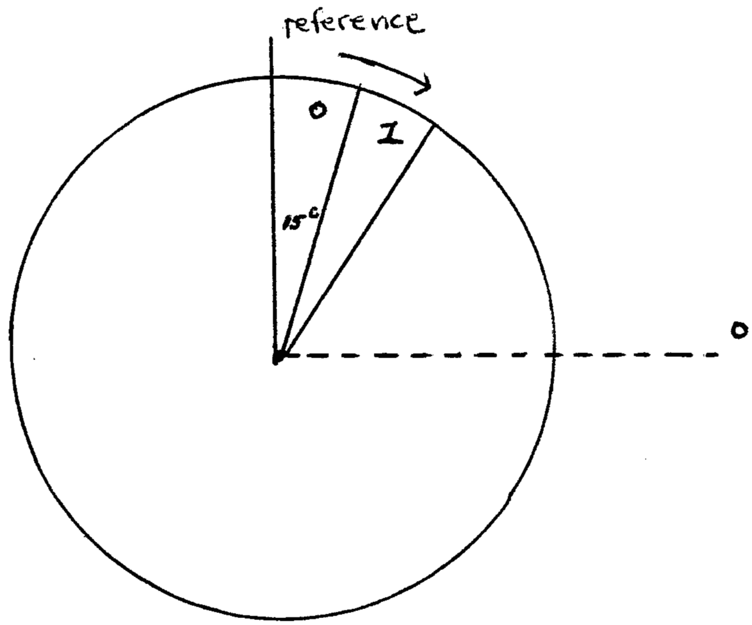
V. DETAILED SYSTEM STRUCTURE

A. Timing System:

The times input by the user or from input data are in year, month, day, hour, minute, seconds. The system converts all times into one number, the "Modified Julian Time" which is in units of average intervals since January 1 of the epoch year hardcoded by



Sector 0,1 PHI histogram : +90° to +90° counterclockwise



Sector 0,1 THETA histogram : +90° to -90° clockwise

Figure 4

the programmer. Arrays with the days for each succeeding year and days since January 1 are used in the conversion (See TIMJUL and JULTIM). For this reason, the epoch year must be a leap year -1, or the count of days will off by 1. The formula is:

$$\text{Modified Julian time} = A*B + \frac{C}{D}$$

where

A = days since epoch year, Jan. 1 of epoch year: A = 0

B = average intervals/day

C = seconds of day

D = seconds/average interval

Thus, January 10, $1^h\ 30^m\ 0^s$ 1973, epoch year = 1971, average interval = 900 seconds is converted to $376*96 + \frac{5400}{900} = 36102$

B. Program Algorithm:

The program may be divided into four main steps:

1. Read in a user namelist set, validating its parameters. If there is no complete namelist set, end.

2. Initialize all required I/O devices (tapes, plotter) for this namelist set.

3. Loop, processing the following steps until data has been processed for this namelist set:

   a. Read in one average interval of sectored data.
   b. Read in magnetic field data to match the interval if required.
   c. Fourier analyze the data.
   d. Print if desired.

e. Output to counts or parameters tapes if desired.
f. Store on disk if any plots are desired until one full plot of data is collected. Then plot appropriate plots.

4. Go back for another namelist set.

VI. ADDING A NEW SATELLITE

There are 6 SD subroutines, INITL, VALID, RECADV, MAGADV, SUB1, SUB2 which must interface to the SI routines. Other SD routines may be called from these 6 routines, according to the need. Pages 2.A - 39 to 47 or MFAP[3] give detailed instructions on altering INITL, VALID, and RECADV. Since that document was written, MAGADV was added to the system. The following describes MAGADV in the same way as MFAP. A correction to MFAP is the name of the framework file. It is currently called 'SBPIO.MULTISAT.FOURIER.SOURCE(SATINDEP)'.

A. MAGADV - Reads in magnetic field data for one interval and stores it in common MAGFLD.

Mandatory Tasks for MAGADV:

1. Zero MAGFLD common
2. Read the magnetic field tape of the current interval, summing records if necessary
3. Fill MAGFLD common with value

Optional Tasks:

MAGADV should not require that every interval will have data on the tape. So when a record is read containing data in the next interval, a flag must be set so that the next time MAGADV is called, this data will be used instead of reading another record.

[3]The Multisatellite Fourier Analysis Program, Jenny S. Jacques, October 1980.

Explicit Changes:

No changes from PIONEER's MAGADV are needed unless the magnetic field tape format is not that designed for this program. In this case, a COMMON block appropriate to the tape must be made, for reading in each record.